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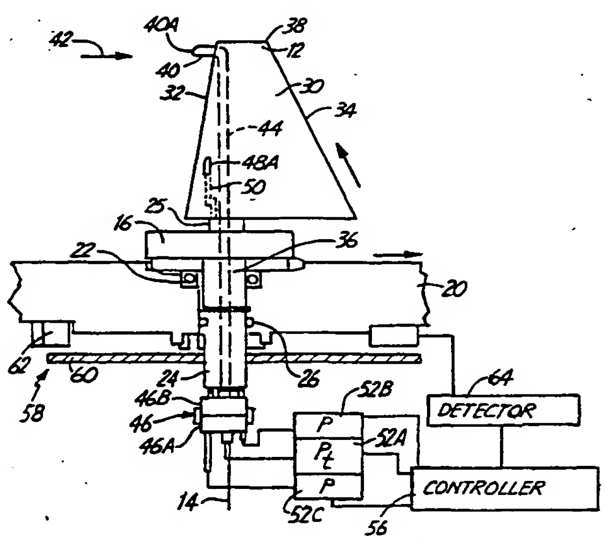
(54) Title: INTEGRATED PROBE AND SENSOR SYSTEM




(57) Abstract: A flow aligned device (12, 66, 100, 122, 150, 176, 214, 234) comprises a probe or vane (12, 66, 100, 122, 150, 176, 214, 234) that will sense angle of attack of an aircraft (10, 74, 106, 124, 164, 180, 210, 231). The flow aligned device (12, 66, 100, 122, 150, 176, 214, 234) is mounted about an axis (14, 116, 130, 156, 200, 220, 240) that is generally perpendicular to an aircraft, and includes pressure sensing ports for sensing pitot pressure (40A, 70, 170, 230, 246) and static pressure (48A, 73, 114, 144, 172) right on the vane (12, 66, 100, 150, 176, 214, 234). The trailing edge (34, 84, 108, 136, 166, 186, 218, 238) of the vane is inclined in a forward direction outwardly from the aircraft body to permit items that may be sliding along the aircraft body from the rear toward the front (e.g. air-to-air refueling baskets) to slide past the vane (12, 66, 100, 122, 150, 176, 214, 234) without being hooked or caught.

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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

# INTEGRATED PROBE AND SENSOR SYSTEM

## BACKGROUND OF THE INVENTION

The present invention relates to a probe or vane that is used on aircraft and is rotatable about an axis generally perpendicular to the surface of the aircraft to sense angle of attack, and also includes pressure ports for sensing pitot pressure, and/or static pressure. The probe is shaped to avoid mechanically hooking objects that might ride across the vane in an opposite direction from the airflow. The vane shape can be selected to suit the existing circumstances, and provides for an integrated pressure sensing or air data parameter sensing system.

Multifunction pressure probes that have a pivoting flow sensitive body used for measuring angle of attack, and which also have at least one pressure sensor are known in the prior art. U.S. Patent 4,672,846 illustrates a device that has a pitot pressure port, and static pressure ports on a flow sensitive vane that provides pressure information as well as angle of attack (AOA). The device is shaped as a traditional AOA vane, with ports on the leading edge.

Another vane that is flow sensitive and contains pressure sensing ports is shown in U.S. Patent 5,257,536. The vane is rotatably mounted and has pitot and static pressure measuring devices, but it has an air foil shaped cross section that extends perpendicular to the aircraft surface.

## SUMMARY OF THE INVENTION

The present invention relates to multiple purpose air data sensing probes, which are configured to provide a reliable indication of air data

parameters from a single probe, thereby reducing drag and costs.

The probes of the present invention are shaped so that they will not be easily damaged by objects moving from the back to the front of an aircraft. This is particularly useful in situations where the probe is installed on an aircraft used in situations where air to air refueling occurs, in that the fuel ports are to the rear (i.e. downstream) of the probes. The basket and hose from the refueling tanker will many times drag or slide along the fuselage from the back toward the front of the aircraft being refueled. When rearwardly swept AOA vanes are used, the refueling hose or basket can be trapped and the probe damaged or even ripped off.

Known rotatable couplings are used to carry individual pressure signals from multiple ports on the probe to the aircraft sensing circuits. The pressure couplings that permit rotation are low friction so they do not affect the rotation needed for angle of attack indication.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic side elevational view of an angle of attack vane mounted on the side of an aircraft;

Figure 2 is a sectional view showing the vane of Figure 1;

Figure 3 is a schematic top plan view of a modified vane configuration having a pitot port and static ports on a vane that rotates to indicate angle of attack;

Figure 4 is a further modified vane constructed similarly to Figure 3, but of a different

shape and mounted in a different way relative to its rotational axis;

Figure 5 is a plan view of a vane similar to Figure 4, but mounted in a different axis relative to the vane body;

Figure 6 is a plan view of a modified exterior vane configuration;

Figure 7 is a further modified form of a vane that has characteristics of the present invention; and

Figure 8 is a modified curved multi-function probe; and

Figure 9 is a further modified curved vane multi-function probe.

## DETAILED DESCRIPTION OF THE ILLUSTRATIVE EMBODIMENTS

Figure 1 illustrates an aircraft 10 that has an angle of attack sensing vane 12 rotatably mounted thereon, for pivoting about a central axis 14 in directions as indicated by the arrows 15. The vane 12 is mounted on a rotatable hub 16 that is suitably supported on bearings relative to the aircraft skin 20. The bearings are illustrated schematically in Figure 2. The bearings support a tubular mounting shaft 24 that is suitably sealed with seals indicated at 26. The shaft in turn supports the hub 16. The hub 16 has a tubular support post 25 that supports the vane 12 in position. The vane rotates about the central axis 14 of the tube 24, and as shown, the general outer shape of the vane is wedge shaped, or it can be generally airfoil shaped, if desired.

The vane in the present form has a main body 30 that has a slightly rearwardly sloping forward edge

32, and a forwardly sloping rear edge 34 that tapers forwardly from a rear inner corner 36 to a rear outer corner 38. Additionally, near an outer tip of the leading edge 32, a short barrel 40 is mounted for sensing pitot pressure. The direction of relative airflow is indicated at 42 and thus the barrel will face upstream. The end of barrel 40 has a port 40A at the leading end of the barrel that will sense the impact pressure. The pressure sensed by port 40A at the end of barrel 40 is carried in a conduit or suitable duct indicated at 44, to a pressure manifold 46 on the interior of the aircraft. The manifold has a stationary section 46A and a rotatable section 46B, and can have grooves on the interior of the mating surfaces for carrying or transferring pressure signals across the manifold. The amount of rotation of the vane will generally be less than 60° in either direction from a centered position and the manifold is made to accommodate that amount of movement.

In addition to probe 40, which has the pitot port 40A at its outer end, there may be a pair of static pressure sensing ports shown at 48A and 48B on the sidewalls of the probe at a suitable location. The ports 48A and 48B are individually connected to conduits or common passageways illustrated in dotted lines at 50, and the pressure in these conduits is also carried or transferred across the manifold 46. The stationary part 46A in the manifold is connected to pressure sensors, including a pitot pressure sensor 42A that will provide an electrical signal to a controller 56, and static pressure sensors 52B and 52C that also provide electrical signals proportional to the sensed pressure to controller 56 or other signal

conditioning circuits. The pressure sensors 52B and 52C are used for determining static pressure, which may be provided by averaging the pressures at ports 48A and 48B. The averaging of the pressures can be done in the controller 56, which can comprise an on board air data computer, or the averaging can be done by plumbing the two conduits 50 together before the pressure signal is provided to a pressure sensor.

Schematically, an angle of attack sensor 58 is illustrated as a movable element 60 that will rotate with the tubular mounting shaft 24, and will rotate relative to a sensor or encoder 62 that is fixedly mounted relative to the aircraft skin 20 (or the aircraft frame) and will provide a signal to a detector 64 which in turn will provide a signal proportional to the amount of rotation of the vane about its axis to the controller or air data computer 56. The sensor 62 can be an optical (i.e. encoder) sensor, for example, or it can be a potentiometer arrangement that provides an electrical signal. Such a potentiometer arrangement for a rotating air data sensor is shown in U.S. Patent 3,882,721. Also an angular encoder sensor arrangement for a rotating vane is shown in U.S. Patent No. 4,672,846. The air data parameters sensed by the probe shown in Figures 1 and 2 can be used for aircraft operation, as desired.

When the airflow direction changes relative to the vane, the vane will rotate as indicated by arrows 15 in a suitable direction to indicate angle of attack relative to the airflow. The rotational movement provides a resolvable signal to the detector 64. Additionally, of course, any changes in pressures will be sensed at the static pressure ports 48A and

48B, and at the barrel 40 and its port 40A, for operation of aircraft instrumentation.

In Figure 3 a modified form of the present invention is illustrated. The vane 66 in this form of the invention is mounted on a suitable rotating support 68, and has a pitot sensing port 70 in its leading edge opening directly through a forward wall 72. It is a flush port that faces upstream, and no separate probe or barrel is needed. The forward wall 72 has a leading edge that is substantially perpendicular to the aircraft skin 74, and the airflow direction indicated at 76 will provide the pitot pressure at port 70. The pressure sensed can be provided to a chamber that is sealed and is indicated at 78 for carrying the pressure signal through the support 68 to the sensors and angle resolvers housed in a housing 80 of suitable design.

The vane 66 has a main body 82 with the leading edge 72, which, as shown, is perpendicular to the aircraft skin, and a trailing edge 84 which inclines in a forward direction relative to the aircraft orientation from an inner rear corner 84A to an outer rear corner 84B. This incline will permit objects such as refueling baskets or hoses to slide along the edge 84 in the directions indicated by the arrow 84C and not get trapped or caught.

The housing 80, which includes angle resolvers potentiometers, sychros and the like, of suitable known design, will provide an output signal indicating angle of attack as represented at block 86. Static pressure sensed is represented at block 88, and pitot pressure is represented at block 90, all of which pressure signals will be provided to an air data

computer or other on board processor 92.

For example, if the probe 66 is a "smart probe" the housing 80 can house the processor internally. The processor will have memory and will be programmable for resolving the angle of attack information, right at the probe and also process the pressure information, and other air data sensing inputs at the housing 80. In any event, the processor or air data computer 92 or a processor in housing 80 can be used for controlling avionics systems 94 as desired.

The operation of the vane 66 will be as shown in Figures 1 and 2, but the shape of the vane or probe is different. The vane 66 also can have static pressure sensing ports 73 in a sidewall 75. There would be ports 73 on both side walls, facing in opposite directions, that can be averaged as shown in Figure 3, to provide the signals to the pressure sensor 88.

Figure 4 represents a different configuration of probe or vane, indicated at 100. The vane 100 is mounted on an offset, rotatable support arm 102, that is rotatably mounted in an angle resolver and housing 104 mounted onto an aircraft skin 106. The probe 100 is "delta" shaped, having a rearward sloped forward edge 106, and a forward sloped rear edge 108, that again will permit objects such as refueling baskets to slide off and not be hooked when they are moved from the rear of the aircraft toward the front as indicated by the arrow 110. A pitot pressure sensing barrel 112 is shown at the leading edge 106 of the vane or probe 100, and static pressure sensing ports 114 can be provided on opposite side

walls of the vane. The axis of rotation indicated at 116 is offset completely from the probe, as shown, and this can bear on the sensitivity of the probe to rotational inputs from the airflow indicated by arrow 120. The center of mass is substantially rearward of the rotational axis in the form of the invention shown in Figure 4.

Figure 5 illustrates a further modified probe or vane shown at 122, mounted on an aircraft skin 124, and supported on a rotating support shaft or tube 126. An angle resolver and circuit housing 128 is provided, and the probe 122 will rotate about an axis 130 on the housing 128. The housing 128 includes sensors and circuits to provide outputs as shown in Figure 3, if desired. The probe or vane 122 has a body 132 with a rearward sloping forward edge 134 and a forward sloping rear edge 136, as in Figure 4, but in this case the support 126 is within the perimeter of body or "envelope" of the vane along a lower edge or wall 138. The vane has a pitot sensing barrel 140 for sensing pitot pressure at its leading end in relation to the airflow direction 142. The vane is hollow and can have static sensing ports at desired locations along the sides such as that shown at 144.

In this form of vane, the outwardly extending and forwardly sloping rear edge 136 also will permit objects moving forwardly to slide off as indicated by the arrow 146 when the objects are moved from the rear of the aircraft toward the front.

Figure 6 is a further modified probe or vane 150 that has a mounting shaft or tube 152 supporting the vane on a resolver housing 154 that can contain pressure sensors, angle resolvers, and similar

circuitry. The probe or vane will rotate about an axis 156, as the airflow direction represented by the arrow 158 changes relative to the probe surface.

The cross section of this probe or vane, and the other probes disclosed can be similar to that shown in Figure 1. The vane 150 has a probe body 160 with a leading edge 162 that extends outwardly from the aircraft skin 164, and a trailing edge 166 is made into steps. The trailing edge 166 includes a forwardly sloping edge portion 166A, adjacent the aircraft skin, and a second slightly outwardly sloping, edge portion 166B that is tapered slightly outwardly in a forward direction. This forms a step that joins an edge portion 166C of the edge 166, which again tapers from the end closest to the aircraft skin forwardly to the outer end 168 of the probe. Thus, the shape of the trailing edge 166 is such that objects that are slid along the aircraft skin 164 from the rear of the aircraft toward the front will slide outwardly along the rear edge and not be hooked in position. A pitot pressure sensing port 170 is formed by a channel cut across the leading or forward edge 162 of the vane 150 is also provided. The channel like pitot port 170 faces the airflow and can be cut into the edge 162 easily. Static pressure ports 172 may be provided at suitable locations on the probe body 160 as well.

Figure 7 illustrates a further modified probe 176 that is of a different configuration. The plan view of the probe 176 illustrates that it is mounted onto a mounting tube or shaft 178 relative to aircraft skin 180, and the tube 178 is connected to carry pressures across a rotating manifold 182 on the

interior of the aircraft. The probe body 184 has a curved or tapered trailing edge 186, and a forwardly inclined leading edge 188 both of which terminate in a barrel portion 190 that is forwardly directed for sensing the pressures created by airflow indicated by arrow 192. A pitot port 194 is used at the outer end of the barrel, for sensing pitot pressure, and static pressure ports 196 are provided on opposite sides of the barrel as well. These pressures will be carried through the rotating mounting tube 178, and across the manifold 182 to suitable controls or processing circuitry shown at 198.

The probe 176 is mounted for rotation about an axis 200 so that it can rotate about this axis relative to the aircraft skin 180, and it will provide angle of attack indications as well as being a barrel type probe for sensing pressures. The axis 200 is positioned so the flow will keep the pitot pressure sensing port 194 facing the air flow.

The curvature of the probe 176 can be modified as desired. Also the probe of Figure 7 can be a probe that projects from the aircraft surface only a small amount, for example about two inches. Such compact or mini probes are used on high performance, supersonic or near supersonic aircraft.

The probes in all forms of the invention can have stops on the rotational mounting so that they will only rotate a selected number of degrees about their axes, and will provide reliable indications of angle of attack. A single probe provides angle of attack, pitot pressure, and static pressure, or provide pitot pressure only from a single pitot pressure sensing port or barrel, or individually

provide static pressure without sensing the pitot pressure. The probes of the present invention all provide the desired pressure signals from a flow aligned device. The flow aligned device is an angle of attack sensing device that can be a generally air foil shaped vane. With proper selection of the axis of rotation, the vane can have a forwardly facing barrel portion such as that shown at 190 in Figure 7. The probes can be mounted in pairs, with one on each side of the aircraft or aircraft. The vanes are made so that they have enough aerodynamic drag to align with the flow.

The angle of attack sensing devices can be RVDT's, potentiometers, synchronous generators, optical outputs, or any other type of sensor desired. The sensors available are accurate and satisfactory. Pitot pressure can be sensed with or without a forwardly extending barrel, and as shown in Figures 3 and 6, the pitot port can be a drilled port or channel cut into the leading edge of the vane. The static pressure sensing ports can be provided or left off as desired. Electrical outputs that are converted to digital form are used for the processors, and the outputs are provided for controlling the aircraft through various avionic systems, as is conventionally done with the signals from existing probes.

Additionally, the probes or vanes are designed so that even though they are rotating probes or vanes, they will be provided with trailing edges that are inclined outwardly in a forward direction to tend to deflect objects that are sliding along the probe or along the aircraft from the rear to the front, such as refueling tubes and baskets.

Figure 8 is a schematic perspective view of a further modified probe that has a different type of curvature and is formed to provide multiple pressure functions as well.

An aircraft skin 210 is used for mounting a housing 212 that rotatably mounts a probe 214. Probe 214 has a concave forward curved edge 216 and a convex rearwardly curved edge 218. The probe is mounted about an axis 220 for rotation for indicating angle of attack. The housing 212 has suitable sensing circuitry in it, and the mounting is such that the probe has a surface 222 that is mounted close to the mounting plate 224 and extends rearwardly from the rotating portions for mounting the probe to prevent objects from jamming between the probe and the mounting plate 224. The curved surface 218 provides a surface that does not incline a substantial amount downstream or rearwardly from a line substantially perpendicular to the mounting plate 224 or the aircraft skin 210, so that objects such as refueling baskets will still tend to slide outwardly along the surface 218 and not cause a jamming. A pitot port 230 is provided at a leading edge, and a static port 232 is provided on the probe as well, as previously explained, and they can be connected to suitable conduits that would lead to sensors inside the housing 212. The direction of airflow is indicated by the arrow 234. The rear edge can be curved differently if desired.

A further modified form of the invention is shown in Figure 9, and it has similarities to Figure 8. An aircraft skin 231 mounts a housing 233, that is made into two sections for rotatably mounting a probe

234. Probe 234 has a slightly concave leading edge 236, and a convex rear or trailing edge 238. The probe 234 is mounted for rotation about an axis 240 for sensing angle of attack, and suitable sensing circuitry is provided along with controls 242.

The inner edge surface 244 of the probe 234 is close to the aircraft skin, and as can be seen, a major portion of the probe extends rearwardly from the mounting housing 232. The rear or trailing edge 238 inclines forwardly from a line substantially perpendicular to the aircraft skin and extending from the inner, rear corner of the probe. Objects such as refueling baskets will tend to slide outwardly along the rear edge 238, and not be caught. In Figure 9, the outer end of the probe 234 is broken away to show the interior of the hollow probe. A pitot pressure sensing port 246 opens to a tube or conduit 248 which is connected to a further conduit 250 that extends through the interior of the hollow probe 234 and is connected through rotating couplings (not shown) in the housing 232. A heater 252 can be wrapped around the tube 248, and connected with leads 254 to the controls 242 as well.

Additionally, a probe surface heater 256 is shown schematically along the sides of the probe 232 and is connected with suitable leads to the controls 242 as well, so that the combined pitot pressure/angle of attack sensor can be deiced fully as desired. The tube 250 also can have a heater wrapped around it if desired. The probe shown in Figure 9 incorporates the same features of a combined pitot pressure and angle of attack sensor and incorporates curved leading and trailing edges, as well as heaters.

It can thus be seen that the probes can have different curved configurations, and still provide the multi-function of providing angle of attack information and pitot pressure. Static pressure also can be provided when desired from the same probe.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

WHAT IS CLAIMED IS:

1. An apparatus for determining angle of attack of an aircraft relative to airflow around the aircraft comprising a sensor body rotatably mounted about an axis of rotation extending laterally outwardly from a surface portion of the aircraft, the axis of rotation being positioned so that the airflow aligns a leading edge of the sensor body toward the flow direction, the sensor body having a trailing edge that inclines in a forward direction outwardly from the aircraft.

2. The apparatus as specified in claim 1, wherein a pitot sensing port is provided at a leading edge of the sensor body for sensing pitot pressure, and a rotating coupling for transferring pressures between the aircraft and the sensor body.

3. The apparatus of either one of claims 1 or 2, further comprising a pair of pressure sensing ports for sensing static pressure on the sensor body.

4. The apparatus of any preceding claim, wherein said sensor body has a leading edge generally perpendicular to the aircraft surface.

5. The apparatus of claim 1, wherein said sensor body has a leading edge that inclines rearwardly from adjacent the aircraft to an outer end of the sensor body.

6. The apparatus of either of claims 1 or 5, wherein the trailing edge inclines continuously forwardly from an end adjacent to the aircraft surface

portion to an outer end of the sensor body.

7. The apparatus of claims 1 or 6, wherein said trailing edge of the sensor body has a step portion, and an inner section of the trailing edge is offset rearwardly from an outer section of the trailing edge by an edge that joins the inner and outer sections.

8. The apparatus of claim 1 and a pitot pressure sensing port provided in a leading edge of the sensor body, said pitot sensing port comprising an opening extending across the body at a leading end thereof and facing in direction of airflow.

9. The apparatus of any preceding claim, wherein said sensor body forms a delta shaped vane.

10. The apparatus of claim 9, wherein said delta shaped vane is supported on an arm, said arm being rotatably mounted on the axis of rotation and extending rearwardly from the axis of rotation to support the delta shaped vane rearwardly of said axis.

11. An apparatus for determining the angle of attack of an aircraft relative to airflow around the aircraft comprising a vane having a body, a support rotatably mounting the vane for rotation about an axis generally perpendicular to a surface portion of the aircraft, the axis of rotation being positioned relative to the vane so that airflow aligns a leading edge of the vane toward the flow direction, the vane having a trailing edge that extends outwardly from the surface portion of the aircraft without substantial

rearward inclination, and having at least portions of the rearward edge that incline forwardly.

12. The apparatus of claim 11, wherein the leading and trailing edges of the vane converge in direction outwardly from the surface portion of the aircraft.

13. The apparatus of claim 11 and a barrel mounted on said leading edge and extending forwardly therefrom, said barrel having an opening at an outer end to provide a pitot pressure port.

14. The apparatus of any one of claims 11, 12 or 13, wherein the vane has at least one static pressure sensing port formed on the vane.

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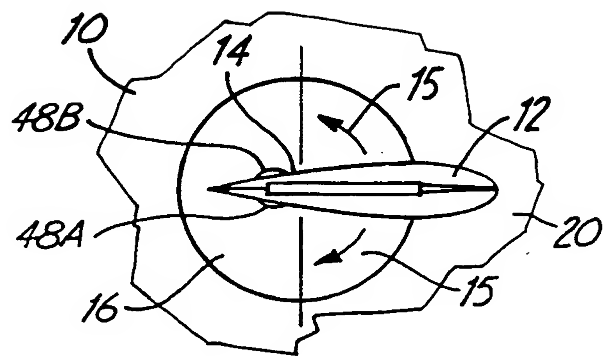
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48B
12
48A
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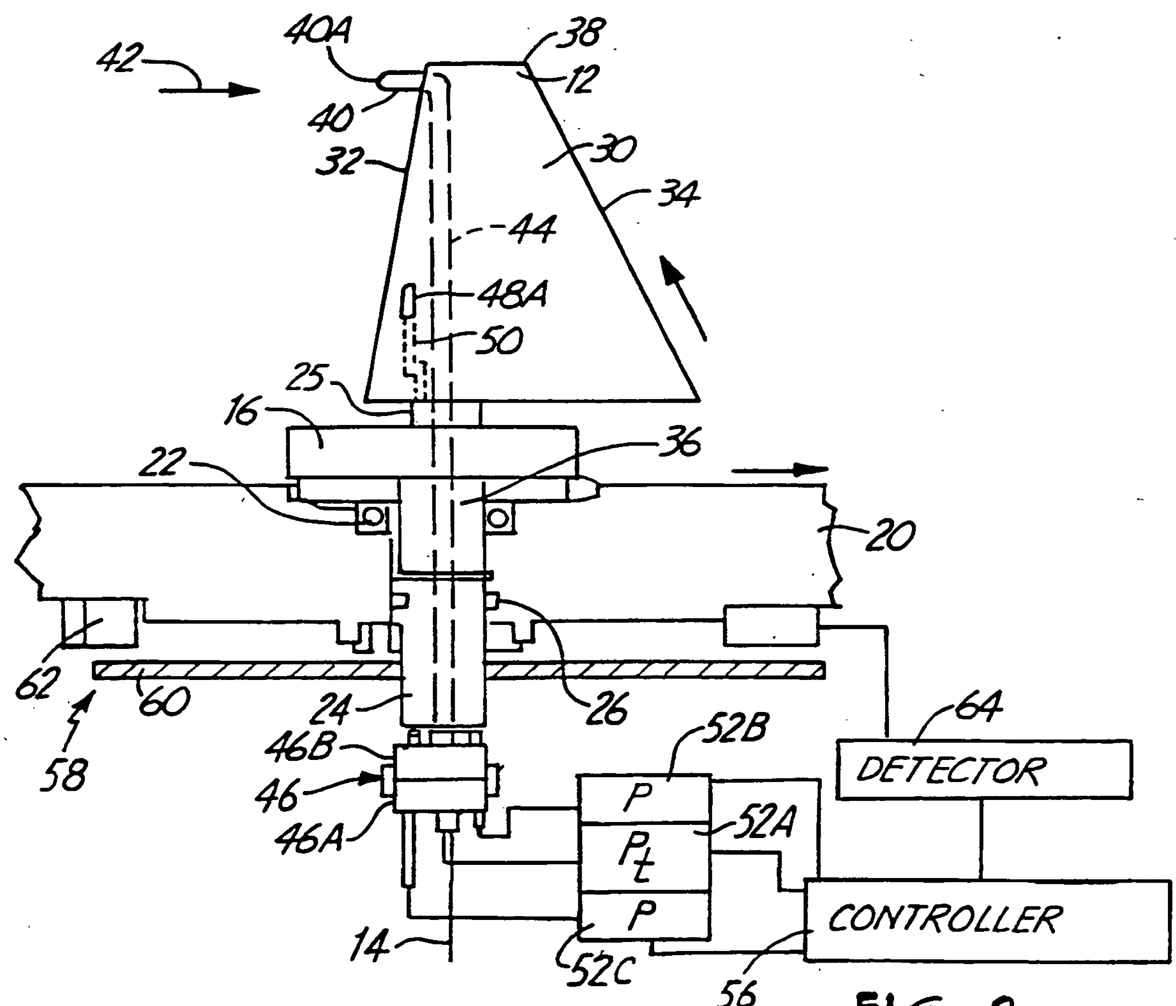
FIG. 1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52C
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FIG. 2

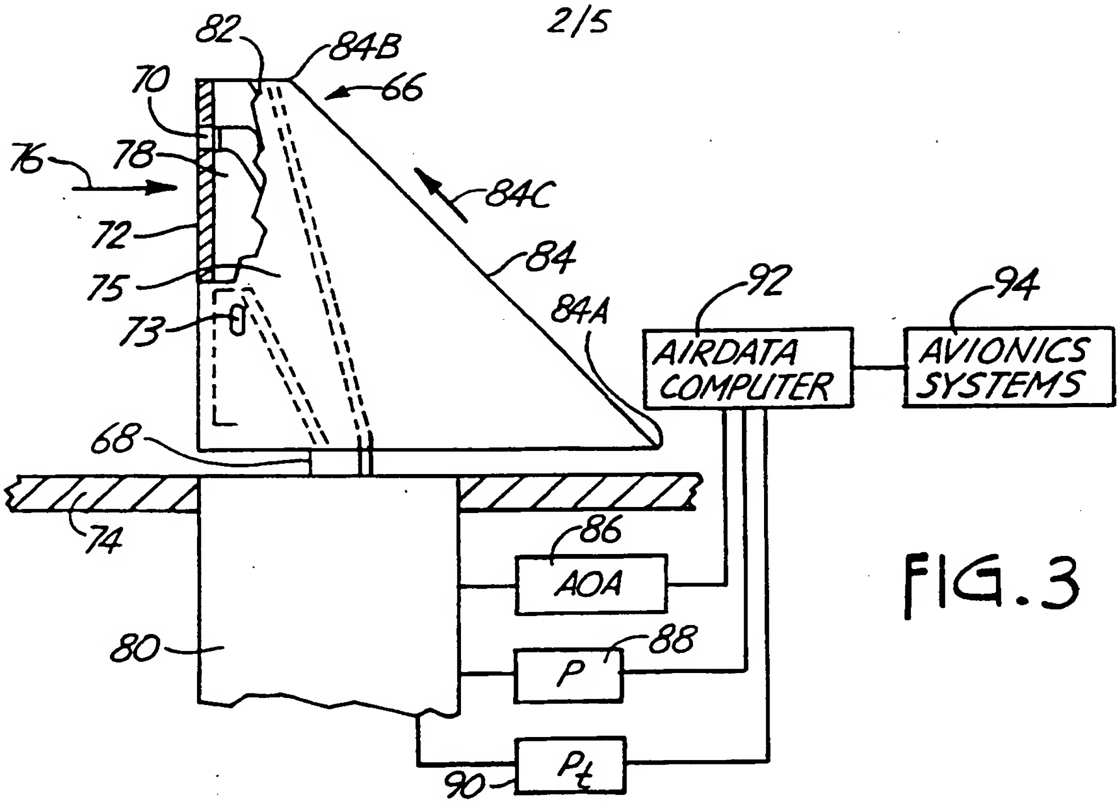



FIG. 3

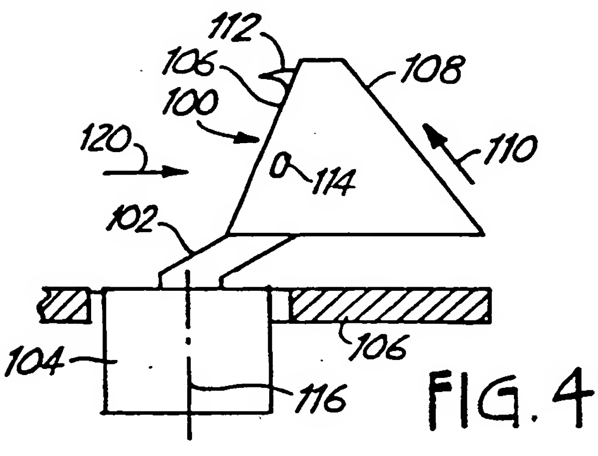



FIG. 4

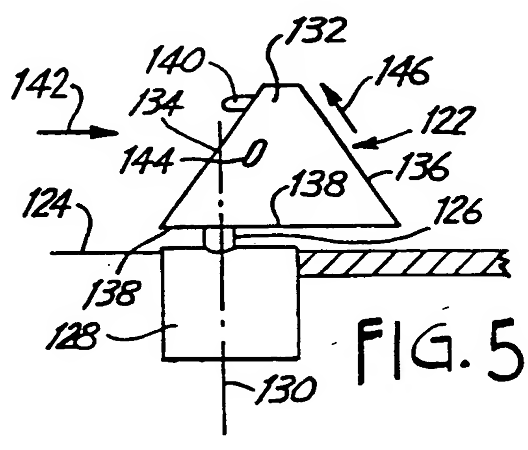



FIG. 5

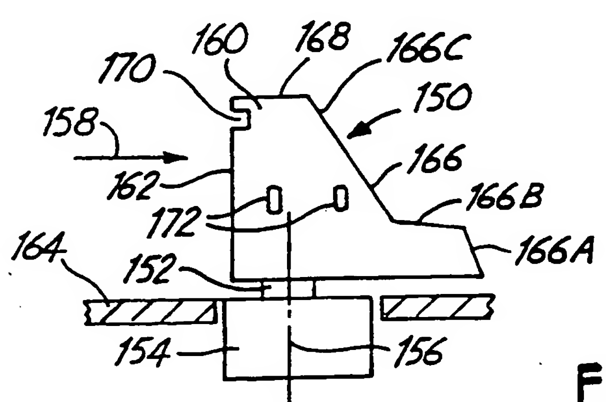



FIG. 6

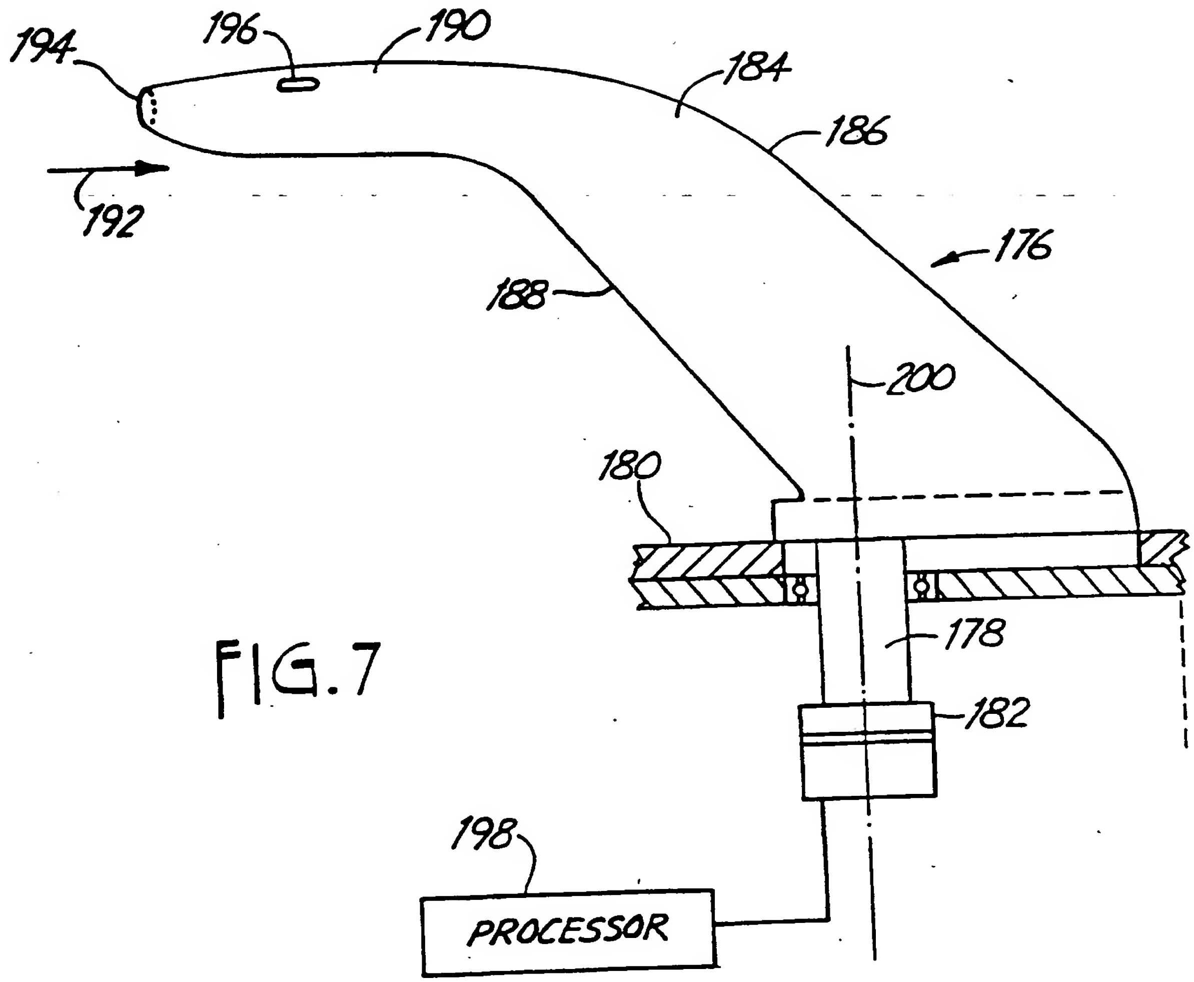



FIG.7

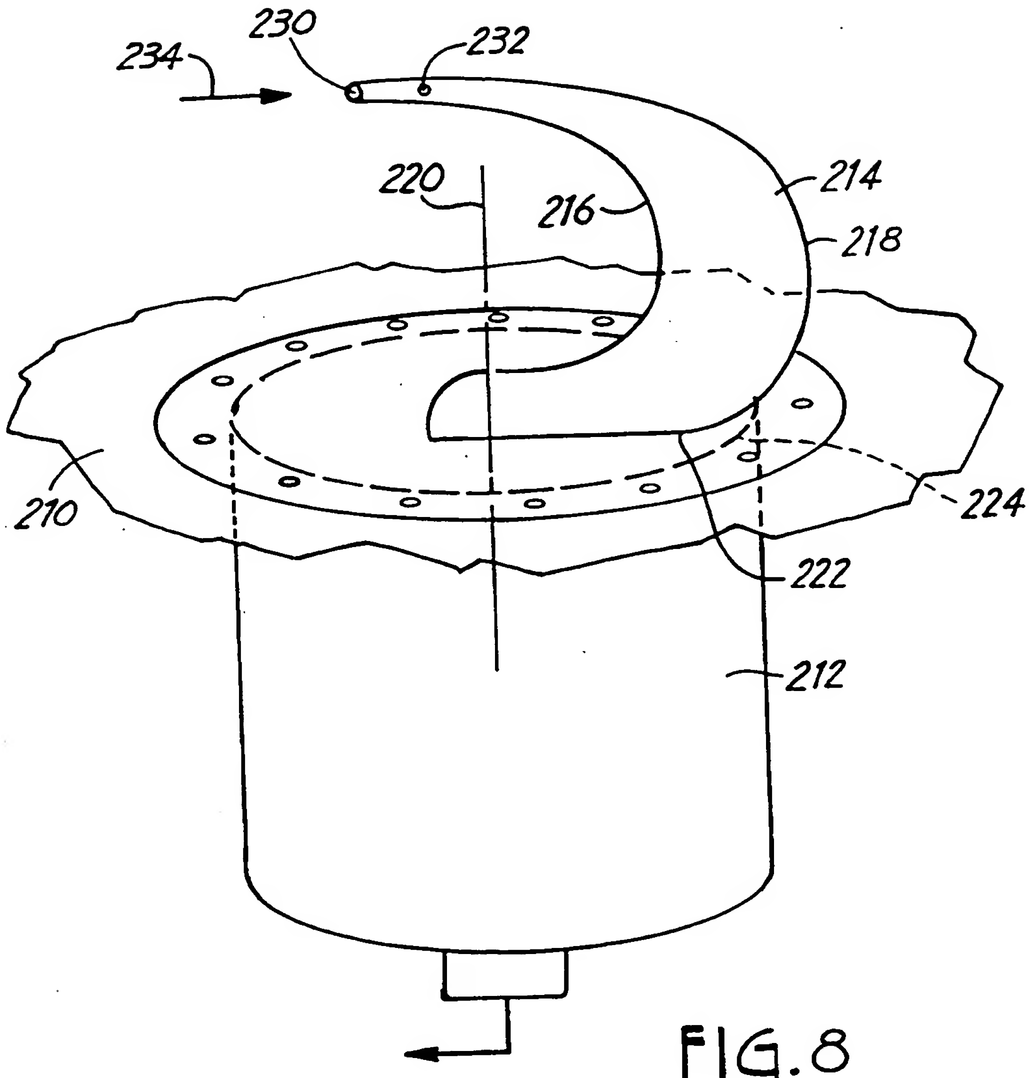
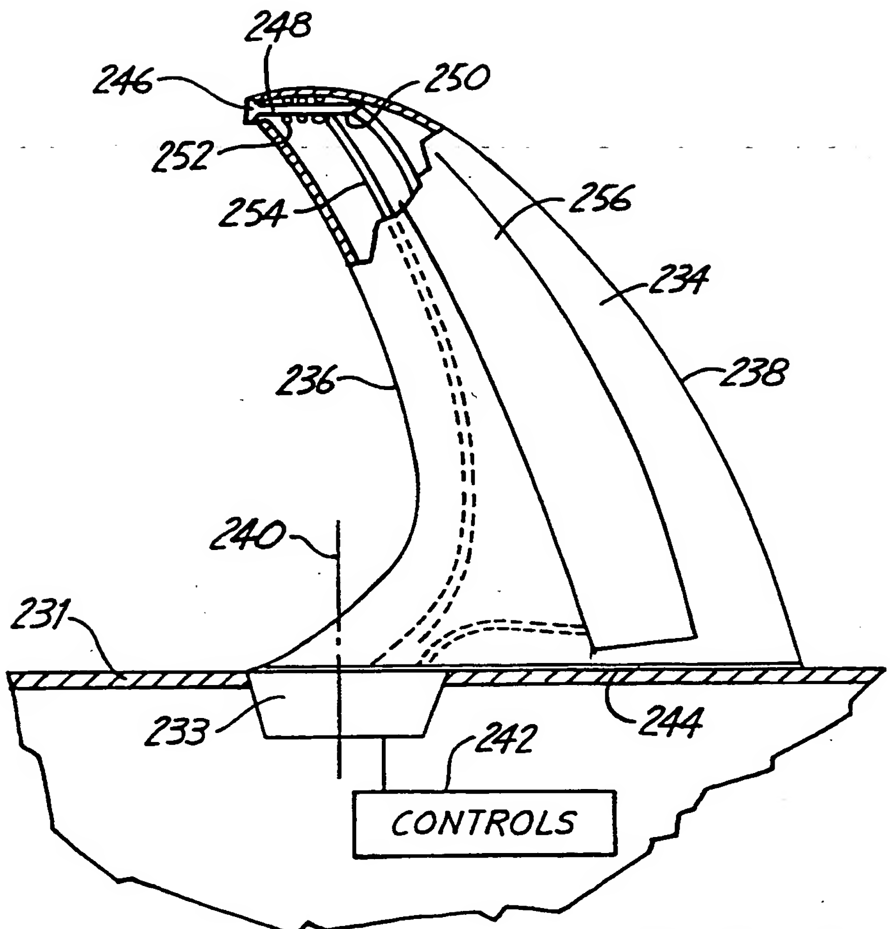



FIG.8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CONTROLS

FIG. 9